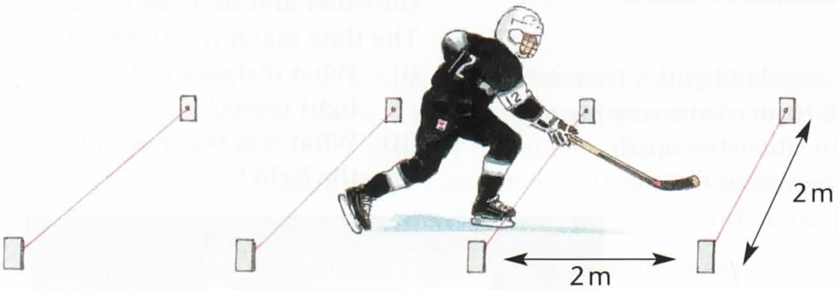
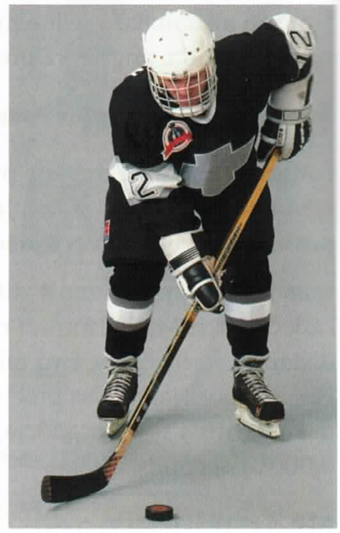
K3 Changing speed

Learn about:
- Steady speed
- Acceleration
- Deceleration

Steady speed

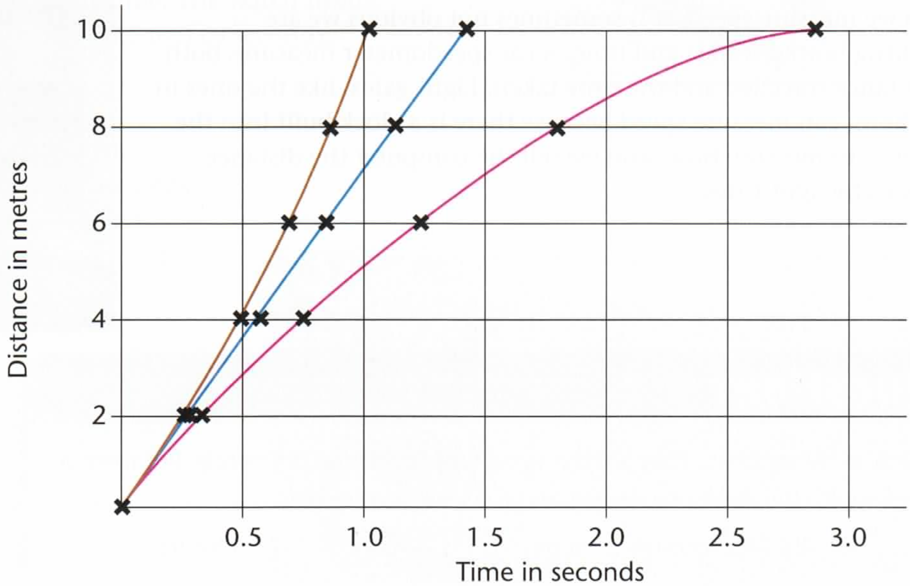
John plays ice hockey. He is taking part in a science experiment about forces and speed. John skates around the rink and then glides 10 metres. There are light gates every 2 metres along the glide path. John breaks the beam when he glides past them and a computer records the time.





Look at this distance–time graph. The **blue** line on the graph shows John gliding through on his skates. The line is straight, with a constant gradient. John is travelling at a **steady speed**. There is almost no friction between the skates and the ice, so he does not slow down.

a **How would the blue line be different if John skated at a higher steady speed?**



Speeding up

John then skates through the light gates, pushing as hard as he can against the ice. The **brown** line on the graph above shows the results. The graph is not straight because John is not travelling at a steady speed. The graph curves upwards: the gradient of the graph is increasing. John is accelerating.

John accelerates because he is pushing against the ice. The push forward is a lot larger than the friction. The forces are unbalanced and the forward force is larger.

The blue arrow in the diagram on the left shows the resultant force. The resultant force is the overall force. If there is a 100 N force forward and a 10 N force backwards, then there is an overall or resultant force of 90 N in the forwards direction. The resultant force causes John to speed up.

b **On another day the ice is less smooth. John still pushes with a force of 100 N but the friction is 25 N. Compare John's acceleration on the two days.**

John repeats the experiment, but with a heavy rucksack. The rucksack increases his mass. He still manages to speed up, but it is more difficult, and he accelerates less. It takes more force to speed up objects with more mass. John is already pushing with all the force he can manage, so he accelerates less.

c **Use this information to suggest why lorries need more powerful engines than cars.**

Do you remember?

Forces are measured in newtons, N. We show forces using arrows. The length of the arrow shows the size and direction of the force.

Slowing down

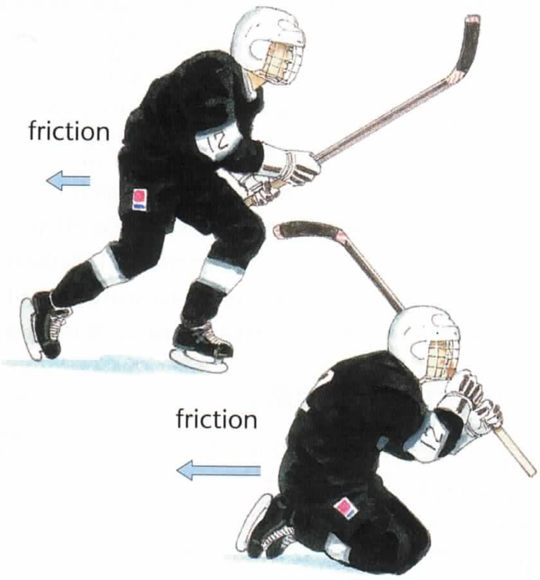
Then John goes through the light gates on his knees. His ice hockey kit will protect his knees.

The pink line on the graph on page 102 shows John sliding through on his knees. The line is not straight. The graph curves downwards: the gradient of the line is decreasing. John is slowing down. The forces are unbalanced. There is a force backwards, friction, but no force forwards to balance it. The unbalanced force slows John down.

d **What would make John slow down even more? Give a reason for your answer.**

John repeats the experiment wearing the rucksack. He slows down less. The friction between John and the ice is the same, so the same force is slowing down a larger mass. The larger the mass, the harder it is to slow down, just like it was harder to speed up.

e **Does a lorry or a car need more force to slow it down? Explain your answer.**



Questions

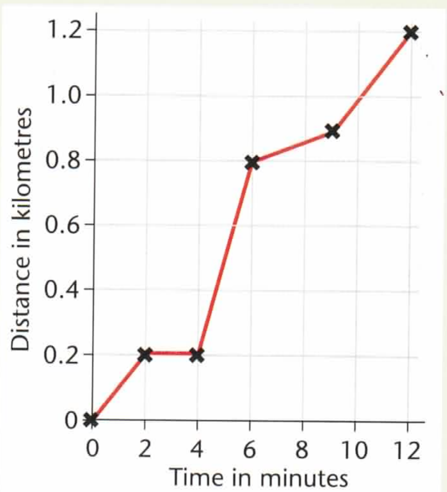
1 A skater pushes forward with a force of 30 N. The friction is 5 N.

a What is the resultant force?

b Is the resultant force forwards or backwards?

c Does the skater speed up, slow down, or travel at a steady speed?

2 Ellen skateboards to her friend's house. Her journey is shown on this distance–time graph.



a Between which two times does Ellen skateboard most quickly?

b Between which two times does Ellen stop?

c Calculate the *overall* speed for the whole journey.

d Sketch a speed–time graph of the same journey.

For your notes:

- If the forces are unbalanced, you can work out the size and the direction of the resultant force. If the forces are balanced there is no resultant force.

Resultant force	Movement	Distance–time graph
none	steady speed	straight line – gradient shows speed
forwards	accelerating	upwards curve with increasing gradient
backwards	decelerating	downwards curve with decreasing gradient

- The larger the mass, the larger the force you need to speed it up or slow it down.

K4 Faster!

Learn about:

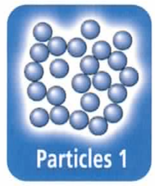
- Thrust
- Streamlining

Thrust SSC

The world land speed record was broken in 1997 by Andy Green driving *Thrust SSC*, shown in this photo. *Thrust SSC* travelled at a mean (average) speed of 763.04 mph.

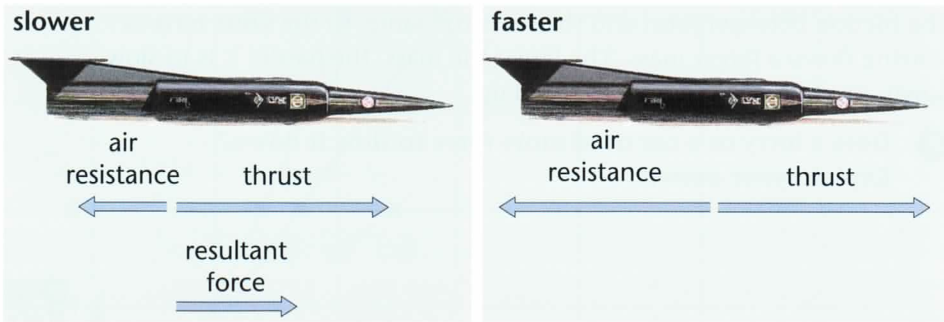
A force pushes the car forward. This force is produced by the car's engines. It is called **thrust**, which gave the car its name. *Thrust SSC* had two very large jet engines (the type used on planes). Each engine can produce a force of 110 000 N, or 110 kN. That is the same as the thrust produced by 500 family cars.

The force backwards, slowing the car down, is caused by friction. When the car moves forward it pushes into air particles. This is called air resistance. Most of the friction is because of air resistance. Although each particle is incredibly tiny, there are a huge number of them. 25 000 000 000 000 000 000 hit every 1 cm^2 of surface when the car moves forward only 1 centimetre. When a car is moving at 763 mph it pushes into a lot of air particles. The air resistance is huge.



Maximum speed

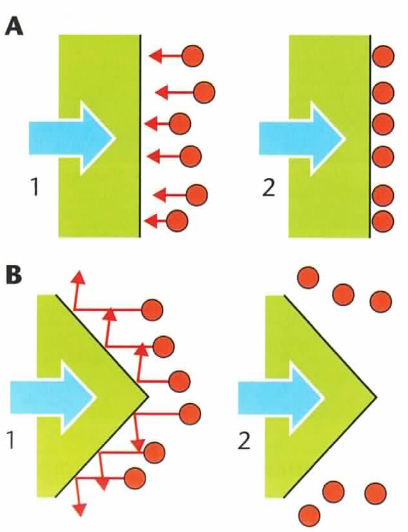
When the car starts up it is moving slowly. It is pushing into fewer air particles every second than later on, so the air resistance is low. The thrust is much larger than the air resistance. The forces are unbalanced and the resultant force makes the car speed up. This is shown in the left-hand diagram here.



As the car speeds up it pushes into even more air particles. The air resistance increases. Finally, the air resistance balances the thrust. The car now goes at a steady speed. This is its maximum speed. This is shown above on the right.

a **Explain why the air resistance is greater for a fast-moving object than for a slow-moving object.**

b **Why does the *Thrust SSC* car reach a maximum speed?**



Streamlining

Cutting down the air resistance increases the maximum speed. It means the car can go faster before the air resistance balances the thrust at its maximum speed.

Smooth, sleek shapes have lower air resistance and are more **streamlined** than lumpy, boxy shapes.

Diagram A shows what happens when you push a flat surface through air. The red balls represent a few of the particles in the air. The surface hits the particles at right angles. The particles will end up being pushed forward, in front of the surface. The engines end up pushing the air, as well as the car.

Diagram B shows what happens with a more streamlined shape. The surfaces are at an angle. The particles bounce sideways. The air ends up to the sides, rather than in front. The engines do not have to push the air as well as the car.

The designer of *Thrust SSC* made it as streamlined as possible. Every surface curves. No part is at right angles to the way the car will be going.

The friction between a moving object and water is often called **drag**. Fast-moving objects are often streamlined to reduce drag or air resistance. Aeroplanes push past many air particles when they fly. Boats and submarines push past many water particles.

Even small bumps on the surface can increase the air resistance or the drag. That's why Olympic swimmers shave off all the hair on their bodies and wear a tight-fitting cap on their heads. Some modern swimmers even wear special body suits like in this photo because the material of the suit causes less drag than skin.

c Penguins are very streamlined. What survival advantage does this give them?

Fuel efficient, not fastest

Thrust SSC may be the fastest land vehicle, but it isn't the most fuel efficient. Every year a competition is held to find the most fuel-efficient design of car. The winner is the car that can travel the furthest on one gallon of fuel. Qualifying cars must have a driver, three or four wheels, travel at an average of 15 mph and complete 10 miles of the course. The winning car in 1996 managed 568 miles per gallon! One of the competing cars is shown in the photo on the left.

d Explain how the shape of the car decreases the amount of thrust needed to travel at a steady speed of 15 mph.

e Why does this lead to a smaller petrol consumption?

Questions

1 The table describes the forces on a car.

	Thrust in N	Friction (including air resistance) in N	Resultant force		Speeding up, slowing down, or steady speed
			Size in N	Direction	
A	200	10			
B	100	150			
C	200	200			

a Copy the table and complete the last three columns.

A car goes down a sliproad onto a motorway, travels along the motorway at high speed and then brakes because there is an increase in traffic.

b Put A, B and C from the table into the correct order to fit with the car's movement.

2 Look at the photo below of a hydrofoil. A hydrofoil is a vehicle that travels along the surface of the water. Use your knowledge and understanding of particle theory to explain:

a why it takes less thrust to push a hydrofoil through air than a boat through water

b why the streamlined 'boat' shape gives the hydrofoil a higher maximum speed than a more 'boxy' shape.

For your notes:

- The pushing force of an engine is called **thrust**.
- The friction of a vehicle pushing past particles is called air resistance or **drag**.
- The air resistance or drag is larger when the vehicle is travelling faster, because it pushes past more particles.
- The maximum speed is reached when the thrust is balanced by the air resistance or drag.